Title: Physics of Model Rockets Addendum -- Using the Pasco™ Rocket Engine Test Bracket

Brief Overview:

This unit is intended as an addition to the 1998 Learning Unit Physics of Model Rockets. It extends the previous work by introducing additional data and calculations made possible by the use of a computer and the Pasco™ Rocket Engine Test Bracket.

Links to National Science Education Standards:

- **Physical Science**
  Students should develop an understanding of motions and forces.

Links to Maryland High School Science Core Learning Goals:

- **Skills and Processes**
  Students will carry out scientific investigations effectively and employ the instruments, systems of measurement, and materials of science appropriately. Specifically, they will utilize data recording software and a computer interface to measure and analyze data. (Expectation 3)

  Students will demonstrate that data analysis is a vital aspect of the process of scientific inquiry and communication. They will analyze collected data to predict the maximum height reached by rockets using various engines. (Expectation 4)

- **Concepts of Physics**
  Students will know and apply the laws of mechanics to explain the behavior of the physical world. They will use mathematical techniques previously discussed and developed in the 1998 Learning Unit “Physics of Model Rockets” and will apply lab data to explain the motion of rockets. (Expectation 1)

Grade/Level:

Grades 8 - 12

Duration/Length:

This activity will add 1 - 2 days to the original rocket Learning Unit.

Prerequisite Knowledge:

Students should have working knowledge of the following skills:

- In addition to the skills previously listed for the Rocket Learning Unit, students should be familiar with the use of computers for taking and analyzing data.

Student Outcomes:

Students will:

- collect and analyze data on the impulse produced by model rocket engines of various sizes.
- compare actual impulse, force, and time of engines to manufacturer specifications.
- test mathematical predictions on actual rockets to determine their accuracy.

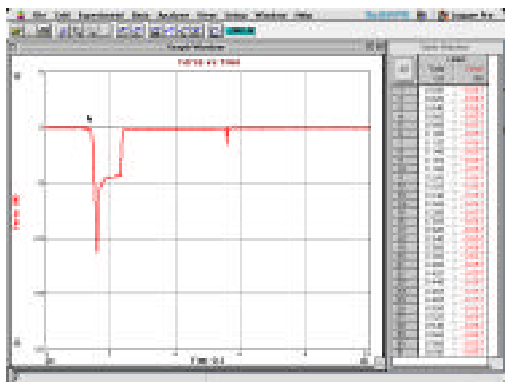
Materials/Resources/Printed Materials:

- Computer (e.g., iMac computer)
- Universal Lab Interface with Logger Pro Software (or comparable interface and program for computer based data collection)
- Vernier Dual-Range Force Sensor (or comparable)
- Pasco™ Rocket Engine Test Bracket
- Equipment to burn several different rocket engines

Development/Procedures:

- Following a discussion on the forces of flight and impulse, as developed previously, students should test various rocket engines. The setup will require an open window or other ventilation, some means of effectively fixing the force sensor and test bracket in place, and the materials listed above. It is left up to the reader to determine how to secure the device to fire the rocket exhaust into the ventilated area, since many possibilities exist. The force vs. time graph supplied by the manufacturer of the rocket should give a reasonable estimate of the maximum force which must be withheld.

- Once the smoke clears, the students should have a force vs. time graph as shown below.



- The graph can be used to calculate the impulse of the engine. You also may want to have students determine the average force, and time of burn, from the data collected.

- Since most graphing programs are capable of integrating the curve for the student, it may be worthwhile to present, at this time, a discussion of what an integral is.

- Students should take the average measurements from the class for each type of rocket. This information could then be used to form their own, experimentally determined, engine performance. They could then compare this with the manufacturer's claimed performance as referred to in the 1998 rocket unit.

Assessment:

On launch day, students should perform the following calculations:

1. Create a list of their class' data for impulse and burn time.
2. Find the average impulse and burn time for the class by sharing data.
3. Calculate the average thrust of the rockets by taking the average impulse divided by the average time of burn.
4. Perform all calculations outlined in the 1998 learning unit to predict the maximum height.

5. During the flights students should record the actual height the rockets obtain and compare them to their predictions.

Challenge questions:

The shape of the force vs. time graph shows the rocket has its maximum thrust in the first moments of launch.

1. If the graph were reversed, so that the peak thrust occurred at the end rather than the beginning, would the rocket travel higher, less high, or the same height? Support your reasoning.
2. Give another reason why having a high initial thrust might be advantageous.

Assessment Scoring Tool:

The following may be used to assess student learning:

Yes or No	Student accurately used the computer to record and analyze the impulse of the rocket engine.
Yes or No	Student correctly determined the average impulse, time and thrust.
Yes or No	Student accurately computed the height of the rocket launch using the computer data and the procedure outlined in the 1998 learning unit **Physics of Model Rockets**.

Success with these questions demonstrates students have successfully met the objectives of the learning unit.

Challenge question assessment:

1. Hopefully students should realize that based on their calculations, which rely on average thrust and impulse, there should be no change in the total height reached by the rocket. Air resistance would change this answer, but it has been previously specified that we are ignoring its effects for this exercise. An answer involving it shows good insight, if poor memory.
2. There are many possible answers to this question, which should primarily be used to check student understanding of the principles involved in rocket flight as a whole. Possible answers include greater rocket stability (inertia), straighter flights (higher speed obtained prior to leaving the guide wire), and even more exciting launches (more sound and smoke). It should be assessed for creativity and soundness of reasoning.

Extension/Follow Up:

The engine's backfire, meant to deploy the recovery mechanism, will also appear on the graph. The size and direction of the recorded burst could lead to an interesting discussion. This is especially true with regard to Newton's Third Law of Motion.

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